[SPECIFICATIONS]

[TITLE OF THE INVENTION]

LIQUID CRYSTAL DISPLAY DEVICE

[BRIEF EXPLANATION OF THE FIGURES]

FIGs. 1A and 1B are schematic cross-sectional views of a twisted nematic (TN) mode liquid crystal display device according to the related art.

FIGs. 2A and 2B are cross-sectional views of a dual display mode liquid crystal display device according to a first embodiment of the present invention.

FIG. 3 is a schematic view of a cellular phone using the dual display mode liquid crystal display device according to the first embodiment of the present invention.

FIG. 4 is a schematic cross-sectional view of a cellular phone using a dual display mode liquid crystal display device according to a second embodiment of the present invention.

FIG. 5 is a schematic cross-sectional view of a dual display mode liquid crystal display device according to a third embodiment of the present invention.

FIG. 6 is a schematic cross-sectional view of a dual display mode liquid crystal display device according to a fourth embodiment of the present invention.

FIG. 7 is a schematic cross-sectional view of a dual display mode liquid crystal display device according to a fifth embodiment of the present invention.

< Explanation of major parts in the figure >

310 : first substrate

312 : first transparent electrode

314 : first polarizer

330 : second substrate

332 : second transparent electrode | 334 : selective reflection/transmission part
336 : second polarizer | 338 : retardation film
340 : liquid crystal layer | 350 : front light unit
360 : key pad | 370 : cellular phone

[DETAILED DESCRIPTION OF THE INVENTION]

[OBJECT OF THE INVENTION]

[TECHNICAL FIELD OF THE INVENTION AND PRIOR ART OF THE FIELD]

The present invention relates to a liquid crystal display device, and more particularly, to a dual display mode liquid crystal display device.

Recently, a liquid crystal display (LCD) device has been in the spotlight as a next generation display device having high value added because of its low power consumption and good portability.

The LCD device, which is not luminescent, is driven by injecting liquid rystal materials between two substrates including transparent electrodes, disposing upper and lower polarizers on outer surfaces of the upper and lower substrates, and controlling light transmittance by an optical anisotropy of the liquid crystal materials.

Hereinafter, FIGs. 1A and 1B are schematic cross-sectional views of a twisted nematic (TN) mode liquid crystal display device according to the related art. FIG. 1A shows progress of light in voltage OFF state and FIG. 1B shows progress of light in voltage ON state.

As shown in FIGs. 1A and 1B, first and second substrates 10 and 30 are spaced apart from and face each other, and first and second transparent electrodes 12 and 32 are formed on inner surfaces of the first and second substrates 10 and 30, respectively. A liquid crystal layer 40 is interposed between the first and second transparent electrodes 12 and 32. First

and second polarizers 14 and 34 are disposed on outer surfaces of the first and second substrates 10 and 30, respectively, and a backlight 50 is located on a rear surface of the second polarizer 34.

The liquid crystal layer 40 is TN mode, molecules of which are arranged parallel with the substrates to be twisted at a right angle between two substrates when voltage is not applied and are arranged perpendicular to the two substrates when the voltage is applied. Light transmission axes of the first and second polarizers 14 and 34 cross each other with right angles.

In voltage OFF state of FIG. 1A, that is, when voltage is not applied, light provided from the backlight 50 passes through the first polarizer 14, wherein a first linearly polarized light is transmitted. The first linearly polarized light is changed to a second linearly polarized light while passing the liquid crystal layer 40 twisted at a right angle, wherein the second linearly polarized light is parallel to the light transmission axis of the second polarizer 34. The second linearly polarized light passes through the second polarizer 34 to display a white picture.

In voltage ON state of FIG. 1B, that is, when voltage is applied, the light provided from the backlight 50 passes through the first polarizer 14, wherein a first linearly polarized light is transmitted. The first linearly polarized light passes through the liquid crystal layer 40, molecules of which are arranged perpendicular to the substrates, without change of phase. Since the first linearly polarized light is perpendicular to the light transmission axis of the second polarizer 34, the first linearly polarized light is blocked by the second polarizer 34, whereby a black picture is displayed.

Like this, in the related art liquid crystal display device, the backlight is used as a light source, and the pictures are displayed in one direction.

[TECHNICAL SUBJECT OF THE INVENTION]

To solve the problems, an object of the present invention is to provide a dual display mode liquid crystal display device, in which utilization efficiency of a screen is increased, by using both sides of a liquid crystal panel as display sides.

To do this, in the present invention, there are a transmissive mode and a reflective mode using outer light and a front light unit, which it is formed of a transparent material such as a wave guide material and increases light efficiency because it can send light to an inside of the substrate or transmit light from the outside into the inside of the substrate and can condense and reflect light toward a predetermined direction.

A lamp for the front light unit includes a light emitting diode.

In addition, to perform a reflective mode using the front light unit, in an incident linearly polarized light component of a first direction, a selective reflection/transmission part is included which selectively reflects a lineerly polarized light component of a second direction perpendicular to the first direction.

The double brightness enhancement film (hereinafter, referred to as DBEF) is used a representative material for the selective reflection/transmission part, and DBEF selectively reflects a light component polarized along a predetermined direction. For example, films having refractive indices with respect to X and Y axes may be multi-layered such that the refractive indices of X-axis may be the same and the refractive indices of Y-axis may be different, and thus light may be transmitted along the X-axis having the same refractive indices and light may be reflected along the Y-axis having different refractive indices.

In another object of the present invention, contrast in the reflective mode of the dual display mode liquid crystal display device is increased.

To do this, in the present invention, a QWP (quarter wave plate), as a retardation film, is disposed to an outer surface of the substrate ajdacent to a key pad, which a user inputs letters through, light reflected at the key pad prevents black brightness properties from being lowered due to the QWP.

The QWP provides a phase differenece of $\lambda/4$ and changes linearly polarized light into ciruclarly polarized light.

[CONSTRUCTION AND OPERATION OF THE INVENTION]

In order to achieve the above-mentioned objects, a first feature of the present invention provides a dual display mode liquid crystal display device including first and second substrates spaced apart from and facing each other; a first transparent electrode on an inner surface of the first substrate; a second transparent electrode on an inner surface of the second substrate; a liquid crystal layer between the first and second transparent electrodes; a first polarizer on an outer surface of the first transparent substrate, the first polarizer having a first light transmission axis; a front light unit on an outer surface of the first polarizer and formed of a transparent material; a selective reflection/transmission part on an outer surface of the second substrate, the selective reflection/transmission part selectively reflecting linearly polarized light corresponding to the first light transmission axis; and a second polarizer on an outer surface of the selective reflection/transmission part, the second polarizer having a second light transmission axis perpendicular to the first transmission axis, wherein a region where the front light unit is situated is referred to as a first display side of a reflective mode, and a region where the second substrate is disposed is referred to as a second display side of a transmissive mode.

A second feature of the present invention provides a cellular phone including a liquid crystal display device of claim 1 as a display device and a key pad adjacent to a second display side of the liquid crystal display device and for inputting.

A third feature of the present invention provides a dual display mode liquid crystal display device including first and second substrates spaced apart from and facing each other; an array element on an inner surface of the first substrate and including a thin film transistor; a first transparent electrode in a region covering the array element; a color filter element on an inner surface of the second substrate; a second transparent electrode is a region covering the color filter element; a liquid crystal layer between the first and second transparent electrodes; a first polarizer on an outer surface of the first transparent substrate, the first polarizer having a first light transmission axis; a front light unit on an outer surface of the first polarizer and formed of a transparent material; a selective reflection/transmission part on an outer surface of the second substrate, the selective reflection/transmission part selectively reflecting linearly polarized light corresponding to the first light transmission axis; and a second polarizer on an outer surface of the selective reflection/transmission part, the second polarizer having a second light transmission axis perpendicular to the first transmission axis, wherein a region where the front light unit is situated is referred to as a first display side of a reflective mode, and a region where the second substrate is disposed is referred to as a second display side of a transmissive mode.

A fourth feature of the present invention provides a dual display mode liquid crystal display device including first and second substrates spaced apart from and facing each other; a color filter element on an inner surface of the first substrate; a first transparent electrode in a region covering the color filter element; an array element on an inner surface of the second substrate and including a thin film transistor; a second transparent electrode is a region

covering the array element; a liquid crystal layer between the first and second transparent electrodes; a first polarizer on an outer surface of the first transparent substrate, the first polarizer having a first light transmission axis; a front light unit on an outer surface of the first polarizer and formed of a transparent material; a selective reflection/transmission part on an outer surface of the second substrate, the selective reflection/transmission part selectively reflecting linearly polarized light corresponding to the first light transmission axis; and a second polarizer on an outer surface of the selective reflection/transmission part, the second polarizer having a second light transmission axis perpendicular to the first transmission axis, wherein a region where the front light unit is situated is referred to as a first display side of a reflective mode, and a region where the second substrate is disposed is referred to as a second display side of a transmissive mode.

Hereinafter, exemplary embodiments according to the present invention will be described in detail with reference to attached drawings.

-- first embodiment --

In the embodiment,

FIGs. 2A and 2B are cross-sectional views of a dual display mode liquid crystal display device according to a first embodiment of the present invention. FIG. 2A shows progress of light in voltage OFF state and FIG. 2B shows progress of light in voltage ON state.

As shown in FIGs. 2A and 2B, first and second substrates 110 and 130 are spaced apart from and face each other, and first and second transparent electrodes 112 and 132 are formed on inner surfaces of the first and second substrates 110 and 130, respectively. A liquid crystal layer 140 is interposed between the first and second transparent electrodes 112 and 132. First and second polarizers 114 and 136 are disposed on outer surfaces of the first

and second substrates 110 and 130, respectively. A front light unit 150 is located on an outer surface of the first polarizer 114.

In the figures, the liquid crystal layer 140 is a TN mode liquid crystal layer. Meanwhile, a liquid crystal layer of other modes may be used.

Light transmission axes of the first and second polarizers 114 and 134 cross each other with right angles. A selective reflection/transmission part 134 is interposed between the second substrate 130 and the second polarizer 136. The selective reflection/transmission part 134 reflects light only parallel to the light transmission axis of the first polarizer 114.

The selective reflection/transmission part 134, beneficially, may include a double brightness enhancement film (DBEF).

In voltage OFF state of FIG. 2A, that is, when voltage is not applied, light provided from the front light unit 150 or outer light sources passes through the first polarizer 114, wherein a first linearly polarized light is transmitted. The first linearly polarized light is changed to a second linearly polarized light while passing the liquid crystal layer 140 twisted at a right angle, wherein the second linearly polarized light is parallel to the light transmission axis of the second polarizer 136. The second linearly polarized light passes through the second polarizer 136 to display a white picture. Here, a region where the front light unit 150 is situated is referred to as a front side (or a first display side), and an opposite region to the front side is referred to as a rear side (or a second display side).

That is, in the liquid crystal display device, the rear side is driven as a transmissive mode and the front side is driven as a reflective mode. Thus, the rear side has a normally white mode, in which a white picture is displayed when voltage is not applied, and the front side has a normally black mode, in which a black picture is displayed when voltage is not applied.

Although not shown in the figures, the front light unit 150, for example, has a patterned structure of saw teeth therein to condense light toward a direction perpendicular to the substrates. A lamp of the front light unit 150 may be equipped as an edge type.

In voltage ON state of FIG. 2B, that is, when voltage is applied, the light provided from the front light unit 150 or outer light sources passes through the first polarizer 114, wherein a first linearly polarized light is transmitted. The first linearly polarized light passes through the liquid crystal layer 140, molecules of which are arranged perpendicular to the substrates, without change of phase. Then, the first linearly polarized light is reflected at the selective reflection/transmission part 134, and passes through the liquid crystal layer 140 again.

Next, the first linearly polarized light goes through the first polarizer 114, and a white picture is displayed in the front side (reflective mode). On the contrary, in the rear side (transmissive mode), a black picture is displayed.

Like this, in the present embodiment, due to a dual display mode using the front light unit and the selective reflection/transmission part, in the rear side of the transmissive mode, the front light unit is used like a backlight to display pictures, and in the front side of the reflective mode, light form the front light unit or outer light sources is reflected at the selective reflection/transmission part to display pictures. Therefore, the front side and the rear side all are used as display regions, and utilization efficiency of a screen is increased. In addition, since other light sources are used besides the artificial light source, i.e. the front light unit, light efficiency is improved.

Hereinafter, when the dual display mode liquid crystal display device is used in folder type cellular phones, progress of light will be described.

FIG. 3 is a schematic view of a cellular phone using the dual display mode liquid crystal display device according to the first embodiment of the present invention. FIG. 3 shows progress of light in voltage OFF state, and overlapped structures will be abbreviated.

As shown in FIG. 3, a cellular phone 270 includes a dual display mode liquid crystal display device 252 and a key pad 260. In the dual display mode liquid crystal display device 252, first and second transparent electrodes 212 and 232 are formed on inner surfaces of first and second substrates 210 and 230 facing each other, respectively. A TN mode liquid crystal layer 240 is interposed between the first and second transparent electrodes 212 and 232. First and second polarizers 214 and 236 are located on outer surfaces of the first and second substrates 210 and 230, and a selective reflection/transmission part 234 is disposed between the second substrate 230 and the second polarizer 236. A front light unit 250 is situated on an outer surface of the first polarizer 214. The region toward the front light unit is defined as a front side (a first display side) and the region opposite to the front side is defined as a rear side (a second display side). The key pad 260 is an apparatus for inputting letters in the cellular phone 270, and is disposed toward the rear side.

At this time, to show a black picture, when voltage is OFF at the front side (reflective mode), some light is reflected at the key pad 260 to cause light leakage because the key pad 260 does not absorb perfectly light.

More particularly, the light provided from the front light unit 250 or the outer light sources passes through the first polarizer 214, wherein the first linearly polarized light is transmitted. The first linearly polarized light is changed to a second linearly polarized light while passing the liquid crystal layer 240 twisted at a right angle, wherein the second linearly polarized light is parallel to the light transmission axis of the second polarizer 236. The second linearly polarized light passes through the selective reflection/transmission part 234

and the second polarizer 236. Therefore, in the rear side (transmissive mode), a white picture is displayed. On the other hand, in the front side (reflective mode), a picture having a low black brightness is displayed because the light passing through the second polarzier 236 is not perfectly blocked by the key pad 260.

To solve the above problem, another embodiment additionally using QWP as a retardation film is proposed.

-- second embodiment --

FIG. 4 is a schematic cross-sectional view of a cellular phone using a dual display mode liquid crystal display device according to a second embodiment of the present invention, and shows progress of light laying stress on a retardation film.

As shown in FIG. 4, in a dual display mode liquid crystal display device 352, first and second substrates 310 and 330 face each other, and first and second transparent electrodes 312 and 332 are formed on inner surfaces of the first and second substrates 310 and 330, respectively. A liquid crystal layer 340 is interposed between the first and second transparent electrodes 312 and 332. First and second polarizers 314 and 336 are located on outer surfaces of the first and second substrates 310 and 330, and a selective reflection/transmission part 334 is disposed between the second substrate 330 and the second polarizer 336. A front light unit 350 is situated on an outer surface of the first polarizer 314. A retardation film 338 is located on an outer surface of the second polarizer 336. The region toward the front light unit is defined as a front side (a first display side) and the region opposite to the front side is defined as a rear side (a second display side).

A key pad 360 is disposed toward the rear side of the dual display mode liquid crystal display device 352. The dual display mode liquid crystal display device 352 and the key pad 360 constitute a cellular phone 370.

The retardation film 338 is a QWP having a phase difference of $\lambda/4$.

In voltage OFF state of the cellular phone, light provided from the front light unit 350 or outer light sources passes through the first polarizer 314, wherein a first linearly polarized light is transmitted. The first linearly polarized light is changed to a second linearly polarized light while passing the liquid crystal layer 340 twisted at a right angle, wherein the second linearly polarized light is parallel to the light transmission axis of the second polarizer 336. The second linearly polarized light passes through the selective reflection/transmission part 334 and the second polarizer 336, and is changed to a first circularly polarized light by the retardation film 338. The first circularly polarized light is reflected at the key pad 360 and is changed to a second circularly polarized light, which is symmetric to the first circularly polarized light right and left. The second circularly polarized light is changed to a first linearly polarized light through the retardation film 338 again, and the first linearly polarized light is blocked by the second polarizer 336.

Like this, in the embodiment, to prevent picture quality from dropping due to the light reflected at the key pad when a black picture is displayed in the front side, the retardation film is additionally attached on the outer surface of the second display side. The retardation film compensates for the light reflected at the key pad and effectively prevents the reflected light from arriving at the front side.

Therefore, the black brightness at the rear side (reflective mode) may be increased to obtain clear image quality having an improved contrast.

-- third embodiment --

In this embodiment, the dual display mode according to the second embodiment is applied to an active matrix type liquid crystal display device, in which thin film transistors are arranged at respective pixels as switching elements.

FIG. 5 is a schematic cross-sectional view of a dual display mode liquid crystal display device according to a third embodiment of the present invention. For convenience of explanation, a front light unit is shown in the lower side of the liquid crystal display device in the context of the figure.

As shown in FIG. 5, first and second substrates 410 and 450 are spaced apart from and face each other. A thin film transistor T is formed on an inner surface of the fist substrate 410, wherein the thin film transistor T includes a gate electrode 412, a semiconductor layer 416, a source electrode 418 and a drain electrode 420. A passivation layer 424 is formed to cover the thin film transistor T. The passivation layer 424 has a drain contact hole 422 that partially exposes the drain electrode 420. A pixel electrode 426 made of a transparent conductive material is formed on the passivation layer 424 and is connected to the drain electrode 420 through the drain contact hole 422. A first alignment layer 428 is formed on an entire surface of the substrate 410 to cover the pixel electrode 426.

The semiconductor layer 416 includes an active layer 416a, which is made of amorphous silicon material (a-Si), and an ohmic contact layer 416b, which is made of impurity-doped amorphous silicon material (such as n+ a-Si). The source and drain electrodes 418 and 420 are spaced apart from each other, and the active layer 416a is exposed between the source and drain electrodes 418 and 420 to form a channel ch, though which carriers pass.

And, a black matrix 452 is formed on an inner surface of the second substrate 450 to cover the thin film transistor T. A color filter layer 454 is formed on the black matrix 452, and a common electrode 456 is formed on the color filter layer 454. The common electrode 456 may be made of the same material as the pixel electrode 426. A second alignment layer 458 is formed on an entire surface of the second substrate 450 to cover the common electrode 456.

A liquid crystal layer 470 is interposed between the first and second alignment layers 428 and 458. The first and second alignment layers 428 and 458 form initial arrangement of molecules of the liquid crystal layer 470.

For example, the pixel electrode 426 corresponds to the first transparent electrode 212 and 312 of the first and second embodiments and the common electrode 456 corresponds to the second transparent electrode 232 and 332 of the first and second embodiment.

A first polarizer 430 is disposed on an outer surface of the first substrate 410 and a front light unit 440 is located on an outer surface of the first polarizer 430. A selective reflection/transmission part 460, a second polarizer 460 and a retardation film 464 are sequentially disposed on an outer surface of the second substrate 450.

-- fourth embodiment --

In this embodiment, an array element is formed on an inner surface of a substrate which a selective reflection/transmission part is attached to.

FIG. 6 is a schematic cross-sectional view of a dual display mode liquid crystal display device according to a fourth embodiment of the present invention. In the fourth embodiment, a color filter element is formed on the same substrate as a selective reflection/transmission part.

As shown in FIG. 6, first and second substrates 510 and 530 are spaced apart from and face each other. An array element 512 is formed on an inner surface of the first substrate 510, and a first transparent electrode 514 is formed to cover the array element 512. Although not shown in the figure, the array element 512 includes a gate line, a data line, and a thin film transistor at a crossing of the gate and data lines. The first transparent electrode 514 corresponds to a pixel electrode. The array element 512 and the first transparent electrode 514 may have the layered structure shown in FIG. 5.

A color filter element 532 is formed on an inner surface of the second substrate 530, and a second transparent electrode 534 is formed to cover the color filter element 532. Although not shown in the figure, the color filter element 532 may include a color filter layer composed of three sub-color filters of red, green and blue and a black matrix between the sub-color filters. The second transparent electrode 534 corresponds to a common electrode.

A liquid crystal layer 550 is interposed between the first and second transparent electrodes 514 and 534. A first polarizer 516 is disposed on an outer surface of the first substrate 510 and a front light unit 560 is located on an outer surface of the first polarizer 516. A selective reflection/transmission part 536 and a second polarizer 538 are sequentially disposed on an outer surface of the second substrate 530. In the case that the liquid crystal display device of the fourth embodiment is used in the cellular phone of FIG. 4, a retardation film 540 may be additionally attached on an outer surface of the second polarizer 538.

The region toward the front light unit 560 is defined as a front side (a first display side) and the region opposite to the front side is defined as a rear side (a second display side).

The structure according to this embodiment may include the structure according to the third embodiment.

-- fifth embodiment --

In this embodiment, a color filter element is formed on an inner surface of a substrate which incldues a selective reflection/transmission part.

FIG. 7 is a schematic cross-sectional view of a dual display mode liquid crystal display device according to a fifth embodiment of the present invention, and basically layered structure is the same as the structure of FIG. 6.

As shown in FIG. 7, first and second substrates 610 and 630 are spaced apart from and face each other. A color filter element 612 is formed on an inner surface of the first substrate 610, and a first transparent electrode 614 is formed to cover the color filter element 612. An array element 632 is formed on an inner surface of the second substrate 630, and a second transparent electrode 634 is formed to cover the array element 632. The first transparent electrode 614 corresponds to a common electrode and the second transparent electrode 634 corresponds to a pixel electrode.

A liquid crystal layer 650 is interposed between the first and second transparent electrodes 614 and 634. A first polarizer 616 is disposed on an outer surface of the first substrate 610 and a front light unit 660 is located on an outer surface of the first polarizer 616. A selective reflection/transmission part 636 and a second polarizer 638 are sequentially disposed on an outer surface of the second substrate 630. In the case that the liquid crystal display device of the fifth embodiment is used in the cellular phone of FIG. 4, a retardation film 640 may be additionally attached on an outer surface of the second polarizer 638.

The region toward the front light unit 660 is defined as a front side (a first display side) and the region opposite to the front side is defined as a rear side (a second display side).

However, the present invention is not limited on the embodiments, and various modifications and variations can be made without departing from the spirit or scope of the invention.

For example, the dual display mode liquid crystal display device of the present invention may be used in other semiconductor devices except for the cellular phones and may further include a retardation film for the purpose of preventing image properties from being lowered due to undesirable reflected light.

[EFFECT OF THE INVENTION]

Like this, according to the liquid crystal display device of the present invention, there are effects as follows.

First, both sides of a liquid crystal panel are used as display regions, and conversion between the reflective mode and the transmissive mode is free.

Second, since the front light unit and outer light are used as a light source, the liquid crystal display device is not limited by surroundings, and consumption in power is minimized.

Third, the black brightness of the reflective mode is improved due to the retardation film located on the outer surface of the liquid crystal display device, and thus the contrast characteristics is improved.